monly known as a "triangular" or "Cholesky" factorization in matrix theory.

This triangular factorization contains all the information needed to compute the optimum MMSE-DFE filter settings and determine the optimum delay parameter Δ. More specifically, the optimum delay, Δ_{opt}, is equal to the index of the largest diagonal element of matrix D in function block **303**. That is,

$$\Delta_{opt} = \underset{1 \le i \le N+v}{\arg\max\{d_i\}}.$$

The optimum feedback filter coefficients **140** (designated as Filter) are set to $\Delta_{opt}{}^{th}$ column of the matrix L in step **304**. The optimum feed forward filter coefficients **130** are obtained in step **305** by multiplying the channel matrix H by the $\Delta_{opt}{}^{th}$ column of the complex conjugate transpose of the L^{-1} matrix and dividing the resulting column vector by the scalar $d_{\Delta_{opt}}$, that is

$$d_{\Delta_{opt}}^{-1} H L^{-*} e_{\Delta_{opt}},$$

where the matrix H is

$$H = \begin{bmatrix} h_0 & h_1 & \cdots & h_v & \cdots & \cdots & 0 \\ 0 & h_0 & \ddots & \ddots & \ddots & \ddots & 0 \\ 0 & 0 & h_0 & h_1 & \cdots & h_v & 0 \\ 0 & 0 & \cdots & h_0 & h_1 & \cdots & h_v \end{bmatrix},$$

and $e_{\Delta_{opt}}$ is a unit column vector which has a "1" in its $_{\Delta_{opt}}$ entry and zeros everywhere else; e.g.,

$$e\Delta_{opt} = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ 1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \begin{matrix} \\ \\ \\ \leftarrow \Delta_{opt}. \\ \\ \\ \\ \end{matrix}$$

Encryption

According to another embodiment of the invention, the data sequence is encrypted. An encryption feature, of any type generally available and known, is added to the data sequence so that the known data sequence will be available only to qualified receivers such as, for example, those subscribers who have paid a periodic or pay-for-view access charge. When applied in combination with other embodiments of the invention, a private data channel packet is received and if it is encrypted, the packet is first decrypted by a receiver. In one embodiment of the present invention this is accomplished by utilizing a keying variable. The un-encrypted or decrypted data bits of the private data channel packet may be used for different purposes, such to provide error detection for other received packets' data, to provide error correction for other received packets' data, to provide data that could be used to remove measured data distortion or distortion that was purposely introduced as part of a pay for quality service, as well as to provide a channel estimate for reduction of multipath effects.

Encryption of the data sequence may be added so that it may be available only to qualified receivers. Encryption/decryption is accomplished by a "classical" or "one-key" cryptographic system such as the Data Encryption Standard (DES) as defined in the Federal Information Processing Standard 46 (1977) and in a mode defined in Federal Information Processing Standard 81 (1980). Further cryptographic architectural information regarding the DES and its modes of operation is contained in the article "Data Encryption Standard," by Hershey and Pomper, and is found in Vol. 5, pp. 227–251 of the Froehlich/Kent *Encyclopedia of Telecommunications,* Marcel Dekker, Inc.

In practice, only digital data to be transmitted is encrypted. As shown in FIG. 5 at the receiver, the received encrypted digital data is input to a decryptor **401** which outputs decrypted digital data. This output is input to a digital-to-analog (D/A) converter **402** which generates an analog waveform from the decrypted digital data.

Dynamic Frame Structure

In one embodiment of the invention, a dynamic or rolling frame/packet structure is used as depicted in FIG. 6. This structure allows a data sequence and staggered slots to be used for countering multipath and, in this way, different multipath delays may be easily estimated. As illustrated in FIG. 6, T stands for Training Sequence Interval and D stands for Data Sequence Interval. Data sequences are bits, while training sequence intervals may contain bits or segments of a specially crafted channel diagnostic waveform. The example shown in FIG. 5 has a repetition length of four frames and inter-training sequence intervals that are spaced so that measurements may be easily made over many different time delays. For example, if there were errors that typically occurred between segments spaced by four microseconds but not one or two or three or five, then it is concluded that there is a strong multipath component at four microseconds.

The training sequence and staggered slots for countering multipath depends upon there being a large number of different inter-interval spacings. By sending known waveforms (modulated bits) in training intervals (i.e., the Ts), it is possible to locate, within an interval of time, the delays of the strong multipath components. For example, if two identical transmitted waveform Ts are separated by four time intervals and the corresponding received Ts are not identical, an average value of their difference can be formed, and this average value will reflect the average multipath component at a delay of four time intervals. In the time domain, let x(t) be a known training sequence and assume that x(t+4) was also transmitted. Assume that there is a strong multipath component with delay τ+4. Assume y(t) and y(t+4), respectively, are received. The average difference is computed as $\delta(t)=y(t+4)-y(t)$, where this average difference removes the effects of uncorrelated multipath from other intervals. What $\delta(t)$ produces is $-kx(t-\tau)$ where k is the strength of the multipath, k<1 and τ~4. If the average value of $\delta(t)$ is not zero, then an estimate of k and τ is solved or, in the alternative, the knowledge that there is a large multipath component with τ~4 is used as ancillary information to aid the second aspect of the invention of estimation of equalizer directly from the channel information.

While the invention has been described in terms of a single preferred embodiment, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

What is claimed is:

1. A method of filtering a digital television transmission comprising the steps of:

generating a packetized first data sequence at a transmitter;

transmitting through a channel, a digital television stream including said packetized first data sequence;

receiving said digital television stream at a receiver and recovering said first data sequence from said digital television stream;

comparing said first data sequence to a second data sequence, said second data sequence being locally generated, to provide a channel estimate;

applying said received television bit stream to an adaptive filter;

adaptively adjusting filter coefficients of said adaptive filter according to said channel estimate such that undesirable channel effects upon said received television stream are filtered from said received television stream.

2. The method of filtering a digital television transmission according to claim 1 wherein the digital television transmission is a high definition television (HDTV) signal and said data sequences are transmitted in a private channel of an MPEG (Motion Picture Expert Group) data channel.

3. The method of filtering a digital television transmission according to claim 1 wherein said first data sequence is corrupted by noise after passage through said channel to said receiver.

4. The method filtering a digital television transmission to according to claim 3 wherein said first data sequence corrupted by noise is used to compute an estimate of channel frequency response.

5. The method of filtering a digital television transmission according to claim 4 wherein the step of comparing comprises the steps of:

computing a Fast Fourier Transform (FFT) of said first data sequence corrupted by noise;

computing a FFT of said second data sequence; and

dividing the FFT of said first data sequence by the FFT of said second data sequence to provide said estimate of channel frequency response.

6. The method of filtering a digital television transmission according to claim 5 further comprising the step of determining said channel impulse response using a quotient from said step of dividing.

7. The method filtering a digital television transmission according to claim 6 wherein the step of determining said channel impulse response comprises the step of windowing an Inverse FFT (IFFT) of said quotient of the dividing step.

8. The method of filtering a digital television transmission according to claim 7 further comprising the step of estimating noise variance by computing average energy of channel estimation error sequence as a function of said windowed IFFT, said first data sequence corrupted by noise and said second data sequence.

9. The method of filtering a digital television transmission according to claim 8 wherein step of estimating noise variance comprises the steps of:

convolving said windowed IFFT with said second data sequence to generate an estimated noiseless output;

subtracting said estimated noiseless output from said first data sequence corrupted by noise to generate a difference signal; and

computing an average energy estimation from said difference signal.

10. The method of filtering a digital television transmission according to claim 9 wherein said channel impulse response and the estimate of noise variance are used to compute optimum equalizer coefficients for the step of adaptively adjusting filter coefficients.

11. The method filtering a digital television transmission according to claim 1 wherein said first transmitted data sequence is encrypted.

12. The method of filtering a digital television transmission according to claim 1 wherein said first data sequence is transmitted in a dynamic or rolling frame/packet structure.

13. A system for filtering a digital television signal comprising:

a generator for generating first data sequences at a transmitter and the transmitter for broadcasting said digital television signal including said first data sequences in a broadcast channel;

a receiver for receiving the digital television signal, said receiver including;

a channel estimator for comparing said first data sequences to second data sequences, said second data sequences being locally generated, and for providing an estimate of the impulse response of said channel at an output of said channel estimator; and

an adaptive equalizer filter including an input for receiving said digital television signal, and filter taps in communication with said output of said channel estimator such that filter coefficients of said adaptive filter are adjusted according to said estimate of said impulse response of said channel.

14. The apparatus for filtering a digital television signal according to claim 13 wherein the digital television signal comprises a high definition television (HDTV) signal and said first data sequences are transmitted in a private data stream of an MPEG (Motion Picture Expert Group) channel.

15. The apparatus for filtering a digital television signal according to claim 13 wherein said first data sequences are corrupted by noise after passage through the channel to the receiver.

16. The apparatus for filtering a digital television signal according to claim 15 wherein said first data sequences corrupted by noise are used to compute an estimate of the frequency response of said channel.

17. The apparatus for filtering a digital television transmission according to claim 16 wherein said channel estimator comprises:

a first Fast Fourier Transform (FFT) processor for computing a FFT of said first data sequences corrupted by noise;

a generator for generating the second data sequences at the receiver;

a second FFT processor for computing a FFT of said second data sequences; and

a divider for dividing an output of said first FFT processor by an output of said second FFT processor to produce said estimate of channel frequency response.

18. The apparatus for filtering a digital television signal according to claim 17 further comprising an estimator for estimating the channel impulse response using a quotient from said divider.

19. The apparatus for filtering the digital television signal according to claim 18 wherein said estimator includes a processor for windowing an Inverse FFT (IFFT) of the quotient of the divider.

20. The apparatus for filtering a digital television signal according to claim 19 further comprising a channel estima-

tor configured to provide an estimate of noise variance by computing average energy of channel estimation error sequence as a function of said windowed IFFT, said first data sequences corrupted by noise and said second data sequences.

21. The apparatus for filtering a digital television signal according to claim 20 wherein said noise variance estimator comprises:

a convolver for convolving said windowed IFFT with said second data sequences to generate an estimated noiseless output;

a subtractor for subtracting said estimated noiseless output from said first data sequences corrupted by noise to generate a difference signal; and

a processor for computing an average energy estimation from said difference signal.

22. The apparatus for filtering a digital television signal according to claim 20 wherein said channel impulse response and said estimate of noise variance are used to compute optimum equalizer coefficients for adaptively adjusting filter coefficients.

23. The apparatus for filtering a digital television signal according to claim 13 wherein said first data sequences are encrypted.

24. The apparatus for filtering a digital television signal according to claim 13 wherein said first data sequences are transmitted in a dynamic or rolling frame/packet structure.

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